

How to Level Shift Using One Gate Logic

Outline:

Voltage translation (level shift) of the control signal may be required when multiple power supplies are used in the system.

This document describes circuit example and notes on using low-voltage one-gate logic ICs (7UL series) without using level shifter ICs.

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1. Introduction

In battery-powered electronic devices, systems are becoming more multifunctional and low-power consumption. Especially in main ICs such as CPUs and MPUs that function as the cores of the systems, finer processes are adopted with lower operating and control signal voltage.

In contrast, when a set is remodeled, existing peripheral ICs that have been adopted are retained in some cases instead of adopting new generations for cost reduction and simpler design. As a result, the use of lower voltage progresses slowly. Therefore, different voltage levels often exist in operating voltages and control signals within the system.

To resolve the voltage differences, dual-supply level shifter ICs have been widely used. This Application Note describes how to resolve this problem more easily at lower costs by using a single-supply logic IC, by taking Toshiba's one-gate logic IC: 7UL series products as an example.

2. Level shift circuits with a dual-supply level shifter IC and with a one-gate logic IC

2.1. Dual-supply level shifter ICs and the one-gate logic IC: 7UL series

A dual-supply level shifter IC is a buffer IC that uses two power supplies (VCCA and VCCB). The IC is specialized for voltage level translation of high level signals and not equipped with the logic functions (AND, OR, NOR, etc.). It operates with VCCA of 1.1 V to 2.7 V and VCCB of 1.65 V to 3.6V. It can support various voltage levels, including voltage level translation from 1.1 V to 3.6 V.

The one-gate logic IC: 7UL series ICs are single-supply logic ICs. The series consists of two types: the 7UL1G series that can operate at 0.9 V or higher and the 7UL1T series that allows for voltage level translation from 1.2 V to 3.6 V. Most of the ICs are equipped with gate functions. They are suitable for applications in which both voltage level translation and logic functions are required simultaneously.

The 7UL1G series ICs can receive input of up to 3.6 V regardless of supply voltage by using the 3.6-V input-tolerant function(*). They are suitable for applications in which logic level translation and voltage level down translation are required.

The 7UL1T series ICs are suitable for applications in which logic level translation and voltage level up translation are required because of the high level threshold voltage of 1.2 V or lower.

* The input-tolerant function prevents current from flowing from the input to the power supply when input voltage is higher than the supply voltage or when the supply voltage VCC is 0 V. Being "tolerant" means having tolerance.

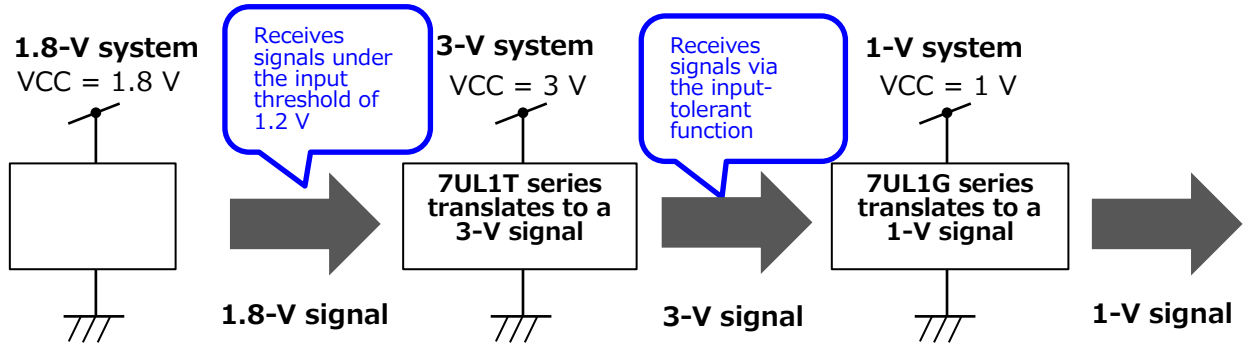


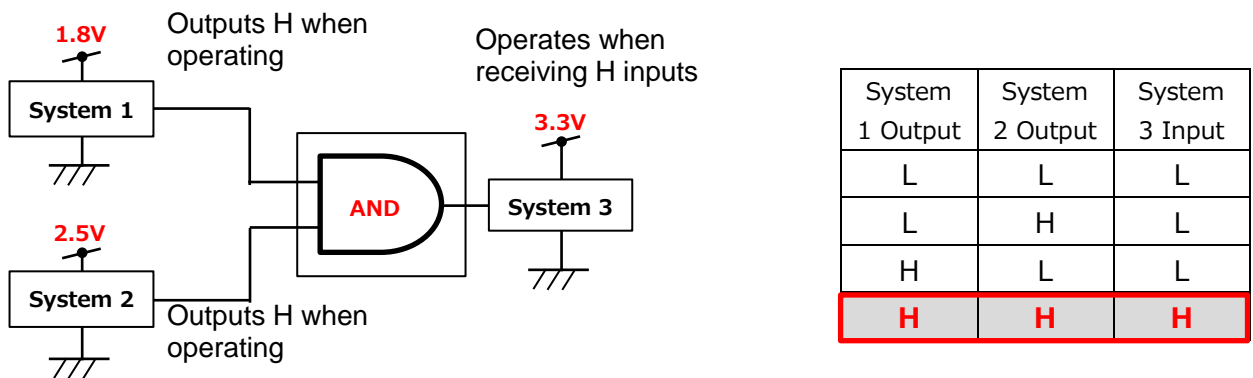
Figure 2.1.1 Example of an application of the 7UL series for interfacing

2.2 Comparison of circuit configurations in which both logic level translation and voltage level translation are required simultaneously

The inputs and output of AND logic used for logic conversion might be in different voltage domains. This subsection compares voltage translation using a dual-supply level-shifter IC and a one-gate logic IC. Figure 2.2.1 shows an example of a circuit using AND logic that requires voltage translation.

Figure 2.2.1 Example of a circuit requiring both an AND circuit and voltage level translation

System 3 (3.3 V) operates when System 1 (1.8 V) and System 2 (2.5 V) operate simultaneously

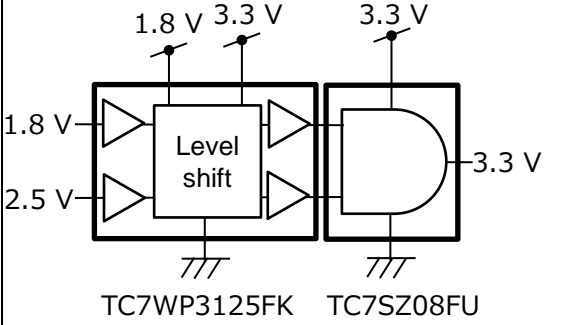
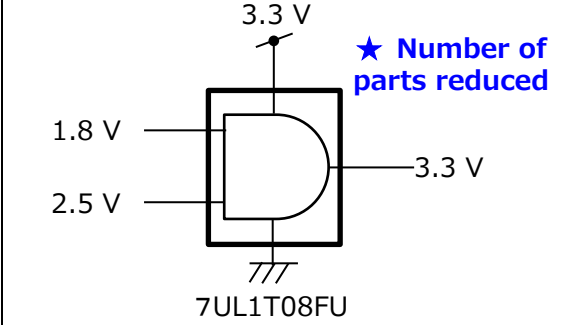


This example shows a circuit in which System 3 operates when both System 1 and System 2 operate simultaneously. System 1 and System 2 output the high level voltage as a control signal when operating. System 3 has a control terminal that operates at the high level voltage. The AND circuit is required to input the high level voltage into System 3 when the control signals of System 1 and System 2 are both high level voltage output. In addition, the system supply voltages are different: System 1: 1.8 V, System 2: 2.5 V, and System 3: 3.3 V. Therefore, voltage level translation is required to match the system voltages.

Conventionally, a dual-supply level shifter IC has been used for this voltage level translation. However, the same operation can be achieved more easily at lower costs by using one single-supply one-gate logic IC, as shown in Table 2.2.2.

Table 2.2.2

Comparison between using a dual-supply level shifter IC and using a single-supply one-gate logic IC

Circuit Configuration	Dual-supply level shifter IC	One-gate logic IC
Product(s) Used	<p>TC7WP3125FK ×1 piece Package: US8</p> <p>TC7SZ08FU ×1 piece Package: USV</p>	<p>7UL1T08FU × 1 piece Package: USV</p>
Major Specifications of Product(s) Used	<p>[TC7WP3125FK] 2-bit unidirectional buffer</p> <ul style="list-style-type: none"> - Supply voltage (input side): $V_{CCA} = 1.1\text{ V to }2.7\text{ V}$ - Supply voltage (output side): $V_{CCB} = 1.65\text{ V to }3.6\text{ V}$ - High-level input threshold: $0.65 \times V_{CCA}$ or lower - 3.6V input-tolerant function - Restriction of turning on V_{CCA} first because it is a dual-supply IC <p>[TC7SZ08FU] 2-input AND</p> <ul style="list-style-type: none"> - Supply voltage: $V_{CC} = 1.65\text{ V to }5.5\text{ V}$ - High-level input threshold: $0.75 \times V_{CC}$ or lower (when $V_{CC} \geq 2.3\text{ V}$) 	<p>[7UL1T08FU] 2-input AND</p> <ul style="list-style-type: none"> - Supply voltage: $V_{CC} = 2.3\text{ V to }3.6\text{ V}$ - High-level input threshold: 1.2V or less - 3.6V input-tolerant function - No restriction on turning on VCC because it is a single-supply IC
Circuit Schematic	 <p style="text-align: center;">TC7WP3125FK TC7SZ08FU</p>	 <p style="text-align: center;">7UL1T08FU</p>
Description of Operation	<p>Voltage level translation: TC7WP3125FK</p> <p>$V_{CCA} = 1.8\text{ V}$ and $V_{CCB} = 3.3\text{ V}$</p> <p>Receives 1.8-V input as well as 2.5-V input via the tolerant function to make the high-level input to the AND circuit 3.3 V</p> <p>AND circuit: TC7SZ08FU</p>	<p>AND circuit: 7UL1T08FU is used</p> <p>Can receive 1.8-V input and 2.5-V input directly because of the high level threshold value of 1.2 V or less</p> <p>Achieves logic level translation and voltage level translation when used with $V_{CC} = 3.3\text{ V}$</p>

Footprint	US8 2.0×3.1 mm Area: 6.2 mm ² USV 2.0×2.1 mm Area: 4.2 mm ² Total: 10.4 mm ²	USV 2.0×2.1 mm Area: 4.2 mm ² Total: 4.2 mm ² ★Footprint: Reduced by 60%
Consumption Current (Quiescent)	TC7WP3125FK: ICCA = 2 μA, ICCB = 2 μA TC7SZ08FU: ICC = 20 μA Total: 24 μA	7UL1T08FU: ICC = 10 μA Total: 10 μA ★Consumption current: Reduced by 58%
Consumption Current (Operating)	Operating at 1 MHz (ICCA+ICCB+ICC) 12 μA + 87 μA + 68 μA = 167 μA	Operating at 1 MHz (ICC) 31μA ★Consumption current: Reduced by 81%

2.3 Advantages and disadvantages of using the one-gate logic IC

The use of the one-gate logic IC: 7UL1T series can reduce the number of parts comprising the circuit (resulting in cost reduction), reduce the footprint, and reduce power consumption. Because of the two power systems, the dual-supply level shifter IC has restrictions on the power-up sequence and requires controlling of the timing of power on/off. However, the one-gate logic IC cannot provide voltage level translation for bidirectional signals. In this case, we suggest the Dual-Supply Level Shifter: TC7MP series and TC7WPB series.

Recommended products for bidirectional data communication

For bus lines and data lines requiring level down and level up simultaneously, dual-supply level shifter ICs are recommended.

Line Type	Number of Lines	Output Type	VCCA (V)	VCCB (V)	Product Name
Bus line (I2C Bus, etc.)	2-bit	Bus switch	1.65 to 5.0	2.3 to 5.5	TC7WPB9306FK
Data line (UART, GPIO, etc.)	4-bit	Buffer	1.1 to 2.7V	1.65 to 3.6	TC7MP3125FK

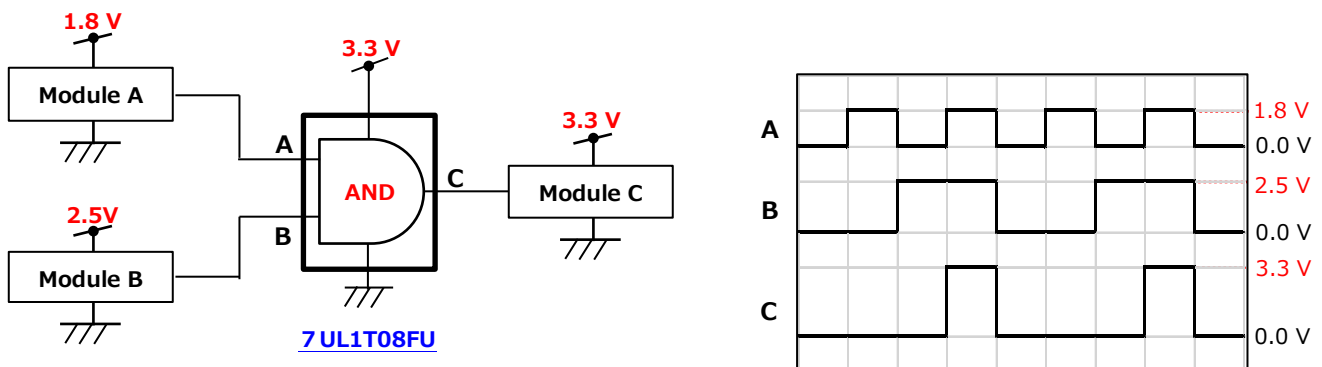
For a list of other dual-supply level shifter IC products ⇒ [Click Here](#)

3 Examples of voltage level translation with the one-gate logic IC

Examples of application circuits that achieve voltage level translation by using the one-gate logic IC: 7UL series are shown below. Examples of application circuits for wireless modules and tablet PCs are provided as typical applications.

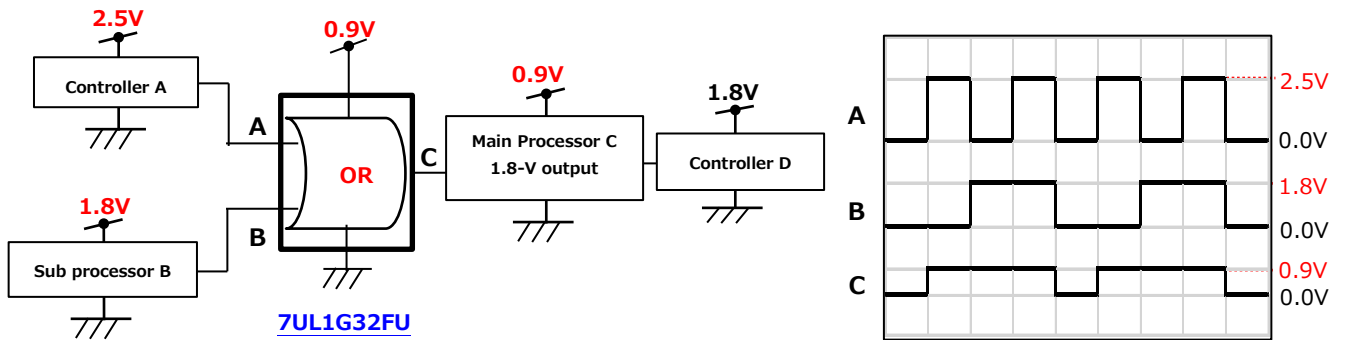
3.1 Leveling up of unidirectional signals

Wireless module: Module C is controlled only when Module A and Module B operate simultaneously



3.2 Leveling down of unidirectional signals

Tablet PC: Main Processor C controls Controller D depending on the states of Controller A and Sub Processor B



4. Summary

Conventionally, a dual-supply level shifter IC has been used for voltage level translation. However, the same operation can be achieved more easily at lower costs by using the single-supply one-gate logic IC: 7UL series.

For single-supply one-gate logic ICs with the level shift function ⇒

[Click Here](#)

For Toshiba's other one-gate logic IC products ⇒

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